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COTTON SEED AND ITS PRODUCTS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., January 30, 1896.

SIR: I have the honor to transmit herewith an article on cotton seed and its products, condensed from original articles by members of the office force and others, and to recommend its publication as a Farmers' Bulletin of this Department.

Respectfully,

A. C. TRUE,
Director.

HON. J. STERLING MORTON,
Secretary of Agriculture.

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COTTON SEED AND ITS PRODUCTS.

INTRODUCTION.

The lint was formerly considered the only valuable product of cotton, but modern enterprise has found a use for almost every part of the plant. In fact, of all the staple crops of the United States not one can be produced with a slighter drain upon the elements of fertility of the soil than cotton, and none excels it in variety and value of its products.

The lint is comparatively poor in fertilizing constituents, containing only 0.34 per cent of nitrogen, 0.10 per cent of phosphoric acid, and 0.46 per cent of potash. It is evident, therefore, that if the lint were the only part of the plant removed from the soil on which it was grown cotton would be one of the least exhaustive of farm crops. The only other product of the cotton plant whose fertilizing constituents need be permanently lost to the soil is the oil, which also contains comparatively insignificant amounts of these constituents. It can be shown "that, even when the seed is taken away along with the lint, cotton still removes smaller amounts of fertilizing materials from the soil than either oats or corn."

If the stubble is turned under (not burned) and the seed or its equivalent in meal is returned to the soil, the growing of cotton exhausts the soil fertility very slowly. In fact, the direct loss to the soil under these circumstances is not more than one-half pound of phosphoric acid, $1\frac{3}{4}$ pounds of potash, and $1\frac{1}{4}$ pounds of nitrogen per acre in a crop of 300 pounds of lint per acre.

The stalks and other refuse on an acre after the seed cotton has been picked amounts to about 850 pounds in weight with average yields of lint. Stock is usually turned in to pasture on this stubble after the last picking. The animals strip off the limbs and pods, leaving finally nothing but the hard and brittle bare stalks.

Air-dry cotton plants, with seed cotton removed, rank as a feeding stuff with the coarse, dry fodders, such as cornshucks, corn stover, and rye, oat, and wheat straw. One hundred pounds of air-dry material contains on the average: Water, 10.01 pounds; ash, 6.13 pounds; protein, 6.35 pounds; fiber, 34.38 pounds; nitrogen-free extract, 41.15 pounds, and fat, 1.98 pounds.

It has been proposed to utilize the cotton stem for the preparation of fiber for cotton bagging, etc., and a process has been patented for this purpose, but the enterprise has not proved successful, owing largely, if

not entirely, to the difficulty of devising a machine that will satisfactorily work up the rough, irregular material. It is claimed that under favorable conditions 5 tons of stalks will yield 1 ton of bark, producing about 1,500 pounds of fiber. Bagging made from this fiber is pronounced by dealers to be of first-class quality. The stalks are also highly valued for fuel in countries such as Egypt, where other supplies are scarce, and the bark of the roots (*Gossypii radiceis cortex* U. S. P.) contains a principle which has long been used for medicinal purposes, its action being similar to that of ergot.

As a by-product of the cotton crop of 1894 there was produced about 4,500,000 tons of seed. From this seed, after deducting enough for planting, there could have been expressed 135,000,000 gallons of oil, leaving as a residue 1,200,000 tons of meal, a valuable feeding stuff and fertilizer, besides an equal amount of fair coarse fodder in the form of hulls.

The uses of these by-products have now reached large proportions and are constantly being extended. It is entirely possible that ultimately cotton will be grown as much for the seed as for the fiber.

Accurate information regarding the value and uses of cotton seed and its products is therefore of great importance not only to the consumer but also to the producer. In the following pages the attempt has been made to give in condensed form the principal facts bearing on this subject.

COTTON SEED.

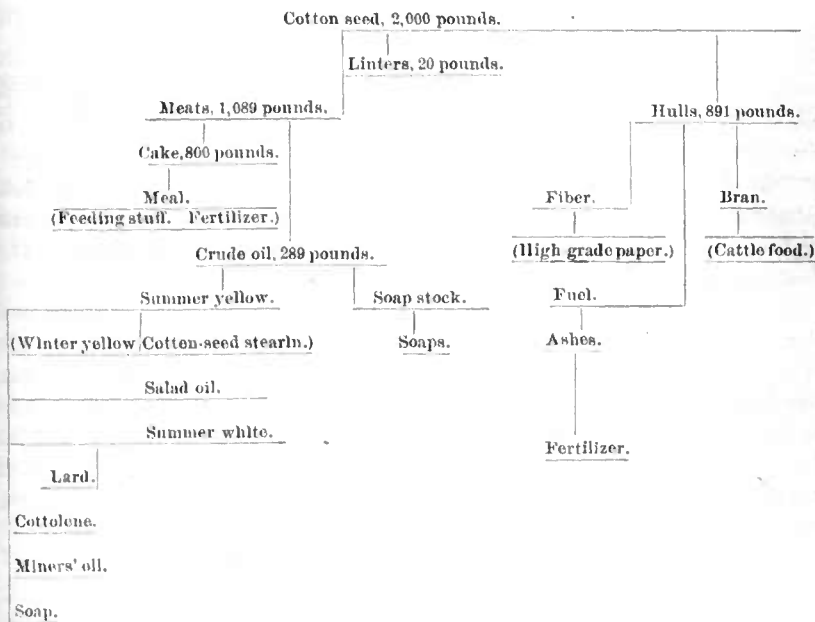
For many years cotton seed was considered only useful to plant. Thousands of tons of this seed were annually burned or dumped into the rivers. But at last it was shown that cotton seed was not only valuable as a fertilizer and feeding stuff in its crude state, but was capable of furnishing products that are among the most important elements in our national industries. The oil is the main product, and is used for a great variety of purposes, which are explained later (p. 9). The residue after the removal of the oil is a valuable fertilizer and feeding stuff, the hulls excellent fuel, the ashes of the hulls a fertilizer rich in potash and phosphoric acid, and the refuse from the oil refining valuable stock for the manufacture of soaps. The seeds also contain a coloring matter which has been used to some extent as a dyestuff. Thus a vast mass of material which was once looked upon as necessarily a waste product has become of very great commercial value.

As it comes from the gin, upland cotton seed consists of the seed proper and the soft down which adheres closely to the seed hulls. This down, known as "linters" to distinguish it from the longer fibers which constitute the lint of commerce, does not need to be removed from that portion of the seed which is reserved for planting, although delinting, besides yielding a valuable commercial product (linters), makes the seed easier to handle and retards fermentation. Experience has shown that

the removal of the linters from the seed prior to decorticating and pressing greatly improves the quality of the oil and other valuable products of the seed. At the oil mills cotton seed, after the removal of the linters, yields practically equal parts of seed coat (or hull) and kernel (or meat). From the latter the oil is expressed, leaving about 800 pounds of cake (or meal) to a ton of seed. The amount of seed worked at the oil mills in the season of 1893-94 is reported at about 1,500,000 tons. This, under favorable conditions, could be made to yield in round numbers 67,000,000 gallons of crude oil, worth, at 25 cents per gallon, \$16,750,000; 600,000 tons of meal, worth, at \$20 per ton, \$12,000,000; 660,000 tons of hulls, worth, at \$3 per ton, \$1,980,000; besides linters to the value of a million or more dollars.

The following diagram, prepared by Grinshaw on the basis of the actual results at oil mills, shows how a ton of cotton seed is utilized:

Products from a ton of cotton seed.



The above diagram was prepared several years ago. Recently the processes of manufacture have been so improved that over 300 pounds (40 to 45 gallons) of oil can be obtained from each ton of seed, and delinting machines have been introduced which remove a much larger amount of linters than is given in this diagram, the proportion of hulls being correspondingly reduced.

As yet, only about one-third of the annual crop of cotton seed is taken to the mills. This is largely due to the lack of transportation facilities. No plan has been devised to preserve cotton seed from heating when stored in large quantities. It must, therefore, be carried to

the mills at the time when the transportation companies are moving the lint. The American Cotton Oil Company reported in 1893 that the estimated cost of the transportation of that portion of the cotton-seed crop crushed by the mills, and its products, by railroad and steamboats amounted to more than \$8,000,000.

Whole cotton seed has been used in the past to some extent as a feeding stuff, but its use for this purpose has now been practically abandoned in the vicinity of oil mills, because of the facts that (1) the lint on the seed and the dust it collects are likely to be injurious; (2) it is not easy to mix the seed thoroughly with other coarse feeds, and (3) the seed is disposed of to better advantage at the oil mills. Its food value is shown by the following summary, compiled from 25 analyses:

Food constituents of cotton seed.

	Fresh, or air-dry, material.					
	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Minimum.....	8.00	2.89	13.02	17.00	7.58	10.40
Maximum.....	17.51	8.00	29.70	32.40	36.70	29.34
Average.....	9.92	4.74	19.38	22.57	23.94	19.45

The digestible food ingredients in 100 pounds of cotton seed, as determined in a number of digestion experiments, are as follows: Dry matter, 89.7 pounds, of which the protein is 11.08 pounds; carbohydrates, 33.13, and fat, 18.44.

Formerly, whole cotton seed was extensively used as a fertilizer in the South, care being taken to kill the seeds by causing them to ferment either in compost heaps or simply in large piles kept wet, but this practice has been largely abandoned, the seeds being disposed of at the oil mills either for cash or in exchange for meal at the rate of 1 ton of seed for 800 pounds of meal. The following summary, prepared from the results of 15 analyses, will serve to indicate the fertilizing value of cotton seed:

Fertilizing constituents of cotton seed.

	Water.	Ash.	Nitrogen.	Phosphoric acid.	Potash
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Minimum.....	7.04	2.80	1.96	0.76	0.73
Maximum.....	9.51	4.96	5.17	1.77	1.63
Average.....	8.42	3.78	3.13	1.27	1.17

METHOD OF MANUFACTURING COTTON-SEED PRODUCTS.

The process through which the seeds are put at the oil mills is thus concisely described by Brant:

The seed when landed at the mill is first examined. If too damp or wet it is dried

by spreading it over a floor with free access of air, exposing it on frames to the sunlight in warm weather, or by kiln-drying. Drying is the exception rather than the rule in the United States. Cotton ginning is so carefully done that the seeds have little or no opportunity to become wet. Besides this, the seed is generally held at the gins for some time before it is sold to the oil manufacturer.

The first process in preparing the dry seed for the mill is to free it from dust. This is effected by shaking it in a screen or in drums lined with a fine metallic net and containing a strong magnet to which any iron nails will adhere, which are frequently present. From the drums the seeds drop into a gutter leading to a machine which removes the lint left by the gin. This is done by a gin constructed for the purpose, with saws closer together than the ordinary cotton gin. An average of 22 pounds of short lint is taken from a ton of the seed. This product, called "linters," is used in the manufacture of cotton batting. The cleaned seeds are then transferred to the sheller, which consists of a revolving cylinder containing 24 cylindrical knives and 4 back knives. The sheller revolves at great speed, and as the seed is forced between the knives the pericarp or hull is broken and forced from the kernel. The mixed shells and kernels are separated in a winnowing machine by a strong blast of air. This removal of the husk makes a vast difference in the meal cake, a desiccated or decorticated cake being five times more nutritious and wholesome than an undecorticated cake.

Being thus cleaned, shelled, and separated, the kernels are carried by a system of elevators to the upper story, and then passed down into the crusher rolls to be ground to flour.

After this crushing the meats drop into a conveyor, which delivers them to the heaters. These are large cast-iron steam-jacketed kettles provided with stirrers which keep the meats moving while they are being cooked. The duration of the cooking varies from twenty to thirty minutes, according to the condition of the kernels and the good judgment of the cook, a human quality here called for the first time to supplement the automatic mechanism that has conducted the seed to this point through all the various processes it has undergone in its journey from the seed house. The object of the cooking is to expand the oil in the meats and render it more fluid, and to drive off the water, which not only reduces the quality of the oil but is liable to work serious injury to the expensive cloths used to envelope the cakes in the press. Very dry meats may sometimes be cooked in twelve to eighteen minutes, while fresh seeds may require forty-five minutes. Close to the heaters stands the "former," which shapes the meats into cakes for the press. The cakes as they come from the former are wrapped in hair-cloth and removed by hand to the press, where they are arranged in a series of boxes, one above the other, between the plates of the press, and subjected to a pressure of 3,000 to 4,000 pounds to the square inch by hydraulic power. The cakes, pressed as solid as boards, are taken from the press, stripped of the cloths, and stacked to dry. When dry they are passed through a cake cracker, which breaks them into fragments of a size suitable to be fed to a mill. The mill grinds these fragments into a fine meal, which is put up into sacks containing 100 pounds. Sometimes the meal is bolted to separate it from small pieces of the hull, which, being tough and leathery, are not readily ground up.

COTTON-SEED OIL.

Notwithstanding the use of cotton as a textile material in the remotest days, there is no early record of the extraction of oil from the seed. The Chinese and the cotton growers of India ground the whole seed in rude mills and fed the cake to their work oxen, and such oil as was extracted by this operation was used for illumination. Among Western nations, perhaps the first mention of cotton-seed oil is to be found in the Proceedings of the Society of Arts, Manufactures, and Commerce for the year 1783, where it is stated that seed from the West Indies had been crushed in a mill in London and the oil extracted. The result was so satisfactory that the society offered a prize to any planter in the British West Indies who would express oil from a ton of seed and make 5 hundredweight of dry, hard cake for cattle food from the residue after extracting the oil. This offer was discontinued after six years of fruitless effort to find a claimant for the prize. In 1826 an oil mill was used in Columbia, S. C., which expressed from cotton seed a very good oil. About 1832 a small cotton-oil mill was operated on one of the islands on the Georgia coast. A Mr. Good engaged in the manufacture of oil in New Orleans in 1847, and used to exhibit a small bottle of cotton-seed oil which he said had cost him \$12,000. In 1860 there were 7 establishments for the manufacture of cotton-seed oil in the United States; in 1867 there were 4 oil mills in the South, and from that time they increased rapidly in numbers, there being 26 in 1870, and 45 in 1880; but it was not until after the latter date that the cotton-seed oil industry approached its present large proportions.

To give some idea of the scale on which the cotton-seed oil industry is at present being conducted, the report of the American Cotton Oil Company in 1891 shows that with a capital of \$33,761,700 it owned 72 crude oil mills, 15 refineries, 4 lard and cottolene plants, 9 soap factories, 15 cotton ginhouses, 3 cotton compresses, 2 fertilizer mixing plants, 1 ocean tank steamship of 4,200 tons and 2,300 horsepower, 335 oil-tank cars, 23 box cars, and 1 barrel car, besides real estate, etc. The sale of their products for the year amounted to \$23,879,400. The following table exhibits the growth of the cotton-seed oil industry in the United States:

Statistics of the cotton-oil industry.

Year.	Estab-lish-ments.	Capital.	Em-ploy-ees.	Wages.	Cost of materials.	Value of products.
1860.....	7	\$351,000	183	\$75,956	\$498,000	\$741,000
1870.....	26	1,225,350	644	292,032	1,333,081	2,205,610
1880.....	45	3,862,500	3,114	880,830	5,091,251	7,690,921
1890.....	119	.....	6,301	1,007,827	14,363,120	19,335,947
1894.....	252	.....	.....	.....	18,000,000	30,000,000

A ton of cotton seed contains on the average about 50 gillons of oil, though the mills have thus far not been able to secure more than 45 gallons per ton. Even at the latter rate an annual crop of cotton seed

amounting to 4,500,000 tons would yield 202,500,000 gallons of oil. Although only about one-third of the crop now reaches the mills, cotton-seed oil is produced in larger quantities than other vegetable oils. This oil finds ready sale in all the markets of the world.

In the United States the decorticated and crushed upland cotton seed yields by expression an odorless, dark, brownish-green oil, having a specific gravity varying from 0.92 to 0.93. After being treated with alkaline solutions a clear, yellow oil, which is odorless and of pleasant taste, is racked off. The residue is called soap stock. The refined oil boils at about 600° F. and congeals at about 50° for summer and 32° for winter pressed oil. American seed yields a clearer oil than the Egyptian or Indian seed, and the uplands seed produces a clearer oil than that from our seacoast. The oil made in Great Britain is not so clear as ours, first, because the seed is mostly Egyptian or Indian, and secondly, because it has not been decorticated. The climate has much to do with the quality of the oil. In some years, owing to more favorable weather conditions, the oil obtained from the seed grown in the western section of the cotton belt is better than that grown in the eastern section, while in other years it is just the reverse. It has been observed at cotton-seed oil mills that in general seed in a wet season contains more oil of poorer quality than in a dry season, but little is known of the change in its composition due to different conditions. It is safe to say that nine-tenths of the oil annually produced in the United States enters into the composition of food products, principally lard substitutes and salad and cooking oils. In pharmaceutical preparations it takes the place of olive oil. It is also used in the packing of sardines and for many other purposes as a substitute for olive oil. By reason of its imperfect drying properties it can not be used as a wood filler, nor for the stuffing of hides in the manufacture of morocco and other leathers. For the same reason it is debarred from use in paints. The refined oil is used to a considerable extent as a lubricant.

In the process of refining, the impurities in suspension are usually allowed to settle, and the clear supernatant oil is drawn off. To the latter from 10 to 15 per cent of caustic soda (10°-28° Baumé), according to the nature of the oil, is added, and the mixture agitated at a temperature of 100°-110° F. for forty-five minutes, the precipitate being allowed to settle from six to thirty-six hours. The residues obtained are disposed of as soap stock, in the manufacture of stearin, etc.

"The yellow oil resulting from this process is further purified by being heated and allowed to settle again, or by filtration, and is called summer yellow oil. Winter yellow oil is made from the above material by chilling it until it partially crystallizes and separating the stearin formed, about 25 per cent, in presses similar to those used for lard."¹ The latter constitutes the true cotton-seed stearin of commerce and is largely used in the preparation of butter and lard surrogates and candles.

Another substance, improperly called cotton-seed stearin, is obtained by distilling with superheated steam the mixture of organic acids formed when the mineral acid is made to decompose the 'foots' obtained during the process of refining cotton-seed oil by alkalies, and pressing out the 'olein' from the distillate after cooling and solidification.—(Wright.)

For the preparation of the white oil of commerce the yellow oil obtained as above is shaken up with 2 to 3 per cent of fullers' earth and filtered.

As a food cotton-seed oil was first used as an adulterant to soften and temper lard intended for use in cold climates. Later on the fluidity of the oil itself was corrected by mixing it with beef fat. This mixture was put on the market under the name of compound or refined lard. It was so kindly received by the public that before long all disguise was dropped and it was sold on its merits in competition with lard. The growing importance of this food stuff as an article of commerce is indicated by the fact that while the exportation of lard only increased 37 per cent between 1884 and 1893, that of cotton-seed oil and its compounds increased 162 per cent.

The soap made from cotton-seed oil is claimed to be especially adapted to wool washing and is now largely used by the woolen mills in this country and also extensively in England and Scotland. The oil has also been found to be excellent for laundry, family, and fancy soaps.

Another by-product in the manufacture of cotton-seed oil is a wash powder made from the soap stock, which, however, owes its principal virtue to the soda or potash used in the refining processes.

COTTON-SEED MEAL.

Cotton-seed meal, as has been already explained, is the ground residue or cake left after the extraction of the oil by pressure. It is bright yellow in color when fresh, with a sweet, nutty flavor, but becomes discolored and deteriorates with age. The black specks seen in some samples show either an accidental impurity or an intentional adulteration with hulls. Its composition depends upon the composition of the seed and on the completeness with which the hulls and kernels are separated and the oil expressed. Improvements in oil machinery are constantly reducing the percentage of oil left in the cake. The following table gives a summary of the results of over 400 analyses of cotton-seed meal with reference to food constituents, and probably shows very accurately the average composition of decorticated cotton-seed meal as found in the American market at the present time:

Food constituents of cotton-seed meal.

	Fresh, or air dry, material.					
	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Minimum.....	5.29	1.72	23.27	1.88	9.13	2.18
Maximum.....	18.32	10.62	52.88	15.15	38.68	30.66
Average.....	8.62	7.02	43.26	5.44	22.31	13.45

As will be seen by the table, cotton-seed meal is poor in carbohydrates (starch, sugar, etc.), but is rich in fat and protein (nitrogenous matter). In fact, it is so rich in the latter constituent that it can be utilized to advantage as a food for animals only when mixed with some coarse fodder rich in carbohydrates, thus furnishing a more evenly balanced ration.

In comparative valuations of feeding stuffs it has been found that cotton-seed meal exceeds corn meal by 62 per cent, wheat by 67 per cent, and raw cotton seed by 26 per cent. As regards digestibility, cotton-seed meal compares very favorably with other concentrated feeding stuffs, as the following statement of the amounts of digestible food ingredients in 100 pounds of meal will show: Protein, 37.01 pounds; carbohydrates, 16.52, and fat, 12.58.

Cotton-seed meal is extensively used as a fertilizer, and for this purpose it is worth from \$20 to \$25 per ton, determining the price on the same basis as that used in calculating the value of other commercial fertilizers. It frequently happens, even in Northern States, that cotton-seed meal can be bought for less than its fertilizing value, calculated on the above basis. Its composition with reference to fertilizing constituents is shown by the following summary of results of 204 analyses:

Fertilizing materials in cotton-seed meal.

	Water.	Ash.	Nitrogen	Phosphoric acid.	Potash.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Minimum	4.34	3.35	3.23	1.26	0.87
Maximum	12.57	9.80	8.08	4.62	3.32
Average	7.84	6.95	6.79	2.88	1.77

Although cotton-seed meal contains considerable percentages of phosphoric acid and potash, a large proportion of which has been shown to be readily available to plants, it is chiefly used as a source of nitrogen in fertilizers. Storer states that "experience has shown that cotton-seed meal is usually as good a fertilizer as regards its nitrogen as either dried fish or flesh scrap, provided the land is not too dry." Cotton-seed meal has given excellent results, especially in the Southern States, as a fertilizer for sugar cane, cotton, and corn. It has also been successfully substituted for barnyard manure in the culture of tobacco.

While cotton-seed meal, as the above facts show, has high value when applied directly as a fertilizer, a more rational practice in many cases is to feed the meal to animals and apply the resulting manure to the soil. From 80 to 90 per cent of the fertilizing materials of the meal will thus be recovered in the manure, and additional benefit will be secured in the production of meat, milk, etc.

COTTON-SEED HULLS.

Cotton-seed hulls, as we have already seen, constitute about half the weight of the ginned seed. Analysis shows them to be principally

crude fiber and nitrogen-free extract matter, these two constituents, with water, constituting more than 90 per cent of the hulls. Hulls even from the same mill, however, vary widely in composition, owing to imperfect removal of the lint or the adherence of more or less of the kernel. The following table shows the minimum, maximum, and average composition of the hulls, compiled from 22 analyses:

Food constituents of cotton-seed hulls.

	Fresh, or air-dry, material.					
	Water.	Ash.	Protein.	Fiber.	Nitrogen-free extract.	Fat.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Minimum.....	7.25	1.05	2.78	35.75	12.41	0.75
Maximum.....	10.73	4.43	5.37	60.95	41.24	5.41
Average.....	11.36	2.73	4.18	45.32	34.19	2.22

The hulls are hard and dry, and usually covered with a fuzzy lint. On superficial examination they appear to be a most unpromising food material, and, in fact, until a comparatively recent period they were universally considered worthless for this purpose.

At least as early as 1870, i. e., soon after the introduction of the oil industry, we have good evidence of local and individual cases of feeding the cotton-seed hulls to live stock. But probably the first attempts at systematically feeding an exclusive ration of hulls and meals on a large scale were made [about 1883]. These cases have been local, confined to the vicinities of the oil manufacturing centers like Memphis, New Orleans, Houston, Little Rock, Raleigh, and Atlanta.—(Stone.)

There are several points in their favor, especially convenience of handling and cheapness. They form a handy medium to dilute condensed food, and give that extension to the animal stomach, especially to ruminating animals (cud-chewing), which is regarded so essential to good, healthy digestion.—(Kilgore.)

They have been found to be a cheap and effective substitute for hay.

Digestion experiments have indicated that 10 per cent of the protein of cotton hulls is digestible, 38 per cent of the fiber, 40 per cent of the nitrogen-free extract, and 77 per cent of the fat; so that 100 pounds of hulls contains the following amounts of digestible food constituents: Protein, 0.42 pounds; carbohydrates (including fiber and nitrogen-free extract), 30.95 pounds, and fat, 1.69 pounds.

The hulls are so bulky as to make storage difficult and they are liable to heat when kept in bulk. For this reason it is usual to put them up into bales weighing 85 to 90 pounds. Baling, as at present practiced, costs about 90 cents a ton, but the hulls keep well and are easily handled. They are sometimes pressed into sacks and preserved in that way, or, before baling and sacking, they may be mixed with definite quantities of cotton-seed meal, bran, cracked corn, or other feeding stuff, to be disposed of as a prepared stock food.

Hitherto a large proportion of the hulls have been used for fuel in the engines at the mills. Their value for fuel is estimated at 80 to 90 cents

a ton where good pine wood is to be had at \$2 a cord or coal at \$3.50 a ton. In other words, a cord of wood is equal in heating power to 2½ tons of hulls, and a ton of coal to 4½ tons of hulls.

COTTON-HULL ASHES.

Cotton-hull ashes have been on the market since 1880 and have come into great demand as a cheap potash supply, especially among tobacco growers. The quality of these ashes varies greatly on account of impurities introduced, principally by the use of other fuel with the hulls. The following table gives a summary of 185 analyses of this material:

Fertilizing constituents in cotton-hull ashes.

	Water.	Phosphoric acid.	Potash.	Lime.	Mag-nesia.	Carbonic acid.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Minimum.....	0.25	2.37	7.02	0.86	2.85	9.56
Maximum.....	22.30	15.37	44.72	19.35	17.15	11.59
Average.....	9.00	9.08	23.40	8.86	9.97	10.57

The potash exists largely as carbonate, which is readily available to plants, but there is also a considerable percentage of silicate of potash, which is difficultly available. The value of cotton-hull ashes depends almost exclusively upon the amounts of potash and phosphoric acid they contain.

FEEDING COTTON-SEED PRODUCTS TO FARM STOCK.

Practical experience has been supplemented by carefully conducted experiments, both in the United States and Europe, with cotton seed, cotton seed hulls, and cotton-seed meal as food for cattle, sheep, pigs, horses, and mules, with the result of demonstrating their high feeding value for all kinds of farm stock, with the possible exception of calves and pigs, to which they have frequently proved fatal.

The high feeding value of whole cotton seed has long been recognized, having been fed raw, roasted, steamed, or boiled to live stock, especially to cattle. Almost from the beginning of cotton culture in this country it has been used to some extent as a feeding stuff, but since the introduction of the cotton-oil industry the superior feeding quality of the by-product—cotton-seed meal—has led to a very general displacement of whole seed by the meal in localities where the latter is easily and cheaply obtained.

The value of cotton-seed meal for producing meat, milk, and butter is well established. It is one of the cheapest of the highly nitrogenous feeding stuffs and is therefore one of the most economical for balancing rations deficient in protein, such as those in which corn is the principal grain. As the analyses on page 10 show, it is very concentrated and should be fed in comparatively small quantities in connection with a

large proportion of coarse food, such as silage, corn, straw, corn stover, cotton-seed hulls, etc., or with good pasturage.

Although milch cows will do well for an indefinite period on cotton seed or cotton-seed meal as the sole grain food, it is better to add a second, such as corn meal or wheat bran, to the ration. If fed to cows in large amounts without proper admixture of other feeding stuffs it is likely to injure the quality of the butter as regards flavor and color. It appears, however, to harden the butter and thus to enable it to stand shipment better. It has also been found to facilitate very materially the rise of cream by gravity.

Referring to the analyses of cotton-seed hulls and meal in the previous pages, we find that neither of them is adapted for use alone as food. The hulls contain a large excess of nonnitrogenous matter and the meal a large excess of protein; each lacks what the other has in abundance. The meal is well adapted by its composition to be fed with the hulls, and the hulls find their proper supplement in the meal. This relation is so evident that the fact that it was not pointed out much sooner is peculiar, although the uninviting character of the hulls as food doubtless had the effect of diverting both scientific and practical investigations from them.

The practice of fattening steers on a diet made up exclusively of cotton-seed hulls and meal commenced about 1883. The business has so grown that it is estimated that probably 400,000 cattle, besides large numbers of sheep, were fattened at and near the oil mills of the South in the season of 1893-94. It is also likely that 100,000 to 150,000 milch cows were fed on rations made up quite largely of cotton-seed hulls and meal. The usual ration for fattening cattle is 3 or 4 pounds of meal at first, which is gradually increased to 6, 8, and even 10 pounds per head per day, and all the hulls they will eat. The proportions vary from 2 to 6 pounds of hulls to 1 of meal, the most common ration at present probably being 4 of hulls to 1 of meal. The feeding is continued from 90 to 120 days. All the information at hand indicates that this practice is both economical and profitable. The diet, apparently, does not injure the health of the animals nor impair the healthfulness of the resulting products, beef, mutton, milk, and butter.

The North Carolina Station gives the following rules for the use of cotton-seed meal and cotton-seed hulls under different conditions:

(1) *For maintenance.*—Where it is desirable to feed an animal just sufficient to maintain it without loss, the following directions may be followed: Hulls from rather green seed may be fed alone, the particles of seed kernels remaining accidentally with the hulls being counted on for maintenance, or, perhaps, even for slow fattening. Dependence, of course, is placed on the amount of kernels left in the hulls. With well-cleaned hulls, however, some cotton-seed meal must be used, depending somewhat on the animal fed. With a cow weighing 950 pounds 1 pound of meal to every 7 pounds of hulls has been shown to maintain the weight and produce about 20 ounces of milk per day. Probably 8 or 10 pounds of hulls to 1 pound of meal when fed in quantity (as much as can be eaten clean) will support life and maintain the weight of neat stock.

(2) *For slow fattening.*—Rations ranging from 7 pounds of hulls to 1 of meal down to 5 or 4 to 1 may be used, depending on the animals fed and skill of the feeder. Each animal should be provided with just what it can consume and no more. With thrifty stock 4 to 1 will produce very good growth, and in mature animals it may be counted on to fatten in from 80 to 100 days.

(3) *For quick fattening.*—Rations for making good beef quickly may range from 4 to 1 down to 2 to 1, or even 1.5 to 1, as we have fed steers successfully on the latter ration. For feeding half-fat cattle from 30 to 40 to 60 days, these last rates are well calculated to increase the body weight. But it is doubtless a good plan to heed the German standard¹ and feed the wider ration at the last, in order that more of the digestible food may be fixed as muscular tissue.

(4) *For milk.*—For the greatest flow of milk we consider it a doubtful practice to feed exclusively on hulls and meal, though both may be prominent articles in the ration. If cotton-seed meal is fed in quantities sufficient to support a cow giving a large flow of milk, it may occasion danger to her health, as it certainly does where fed to pigs and calves in like manner. When a cow has passed about four or five months of gestation, and the flow of milk has greatly diminished, she may be put on a ration of hulls and meal, which may be varied from 4 to 1 to as much as 7 or 8 to 1 of hulls to meal until she has dried off. This will support the cow well. It would be well all this time, however, to be feeding once per day some hay, stover, straw, or let her graze part of each day.

For two or three weeks before calving the cow's ration should be changed by substituting a succulent diet or bran for the cotton-seed meal. A week before calving, if not already affected by the succulent diet, the cow should be thoroughly purged with Glauber's or Epsom salts, in one-pound dose. Care should be exercised to see that the bowels remain loose; if not, repeat the dose at intervals, as needed, until the cow has come to her full yield of milk after calving.

(5) *For other stock.*—To other than ruminating animals, the use of either cotton-seed hulls or meal is yet of doubtful expedience. Hulls are considered too bulky for horses, but cotton-seed meal may often be fed in small quantities to good advantage with the usual wide rations. Its action, however, on the nervous system is yet untried, so far as we are informed, and it would only be safe as a small part of a ration to be used, much as linseed meal or flaxseed is sometimes used. This meal, in small quantities, is not so laxative as linseed meal.

EFFECT ON THE HEALTH OF ANIMALS.

Injurious effects of cotton-seed products on certain kinds of farm stock have frequently been observed, and their cause has been the subject of many careful investigations, but it is still an open question whether the injurious principle is an original constituent of the cotton-seed products or whether it is developed as the result of decomposition before feeding or of a change within the animal's body. The indications are, however, that the chief danger lies in the use of material which has undergone fermentation. All experience goes to show that fresh cotton-seed products, especially cotton-seed meal, can be safely fed to beef cattle, milch-cows, and sheep, although on account of its extreme richness it should be used with care in connection with less concentrated feeds. It may be used with safety in larger quantities in winter feeding than in summer feeding. There is no doubt that its use as a food for young animals, especially pigs and calves, is attended with

¹ See Farmers' Bul. 22 of this Department.

great danger. Its effect on horses and mules has not as yet been sufficiently studied to warrant conclusions, but a few instances are reported in which it has been fed regularly for long periods with good results.

SUMMARY.

Cotton stands preeminent among farm crops in the ease and cheapness of its production as compared with the variety and value of its products.

The amount of soil fertility actually removed in a crop of cotton, even when both seed and lint are sold, is smaller than that removed by either corn or oats, and when care is taken to return the seed or an equivalent in meal to the soil these losses are almost insignificant.

Cotton roots furnish a useful drug; the stems and leaves together have a certain value as fodder, and the stems alone have been utilized with some success for fiber and for fuel; but next in importance to the lint stands the seed, which furnishes a great variety of valuable products whose applications are being rapidly extended.

The 1,500,000 tons of seed worked at the oil mills during the season of 1893-94 could have been made to produce under favorable conditions in round numbers 67,000,000 gallons of crude oil, worth, at 25 cents per gallon, \$16,750,000; 600,000 tons of meal, worth, at \$20 per ton, \$12,000,000; 660,000 tons of hulls, worth, at \$3 per ton, \$1,980,000; besides linters to the value of a million or more dollars.

The oil is the main product of the seed. The larger portion of the oil manufactured in this country is used in the preparation of food products, principally refined lard and salad and cooking oils. It is also used in the manufacture of soaps of various kinds, washing powder, cosmetics, to some extent for illuminating purposes, as a lubricant (when refined) in the manufacture of bolts and nuts, and generally as a substitute for olive oil. The fact that it is not strictly a drying oil, however, renders it unfit for use in paints. The refuse from the refining of the oil is valuable "stock" for the manufacture of soap.

The residue (cake) after the removal of the oil is a valuable fertilizer and feeding stuff, the hulls excellent fuel, the ashes of the hulls a fertilizer rich in potash and phosphoric acid. The seed also furnishes a dyestuff which has been used to some extent.

It is believed that an increased knowledge of the nature and value of the products of cotton seed will extend their use until it will be found profitable to work up the whole available crop of seed into commercial products instead of utilizing in this way only about one-third of the crop, as is now the case.